Supplementary figures

Figure 1: Observed vs. modelled precipitation for Umeå during the period 1860−1950

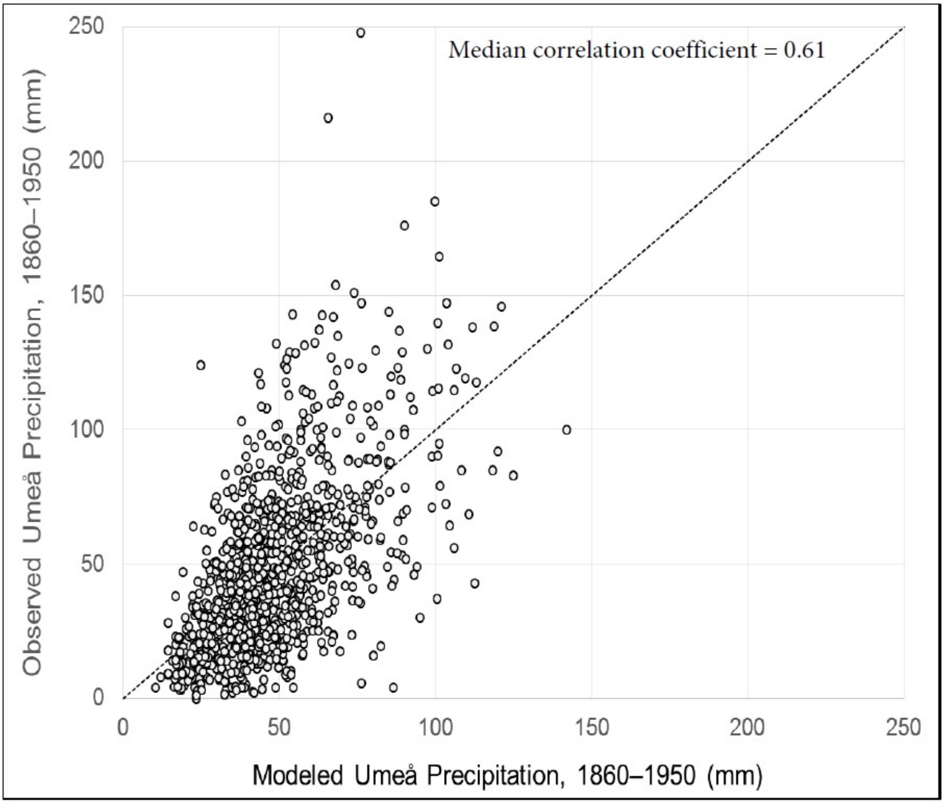


Figure 2: Relationship between temperature and mortality (log relative risk) for different lags during the period 1800−1859

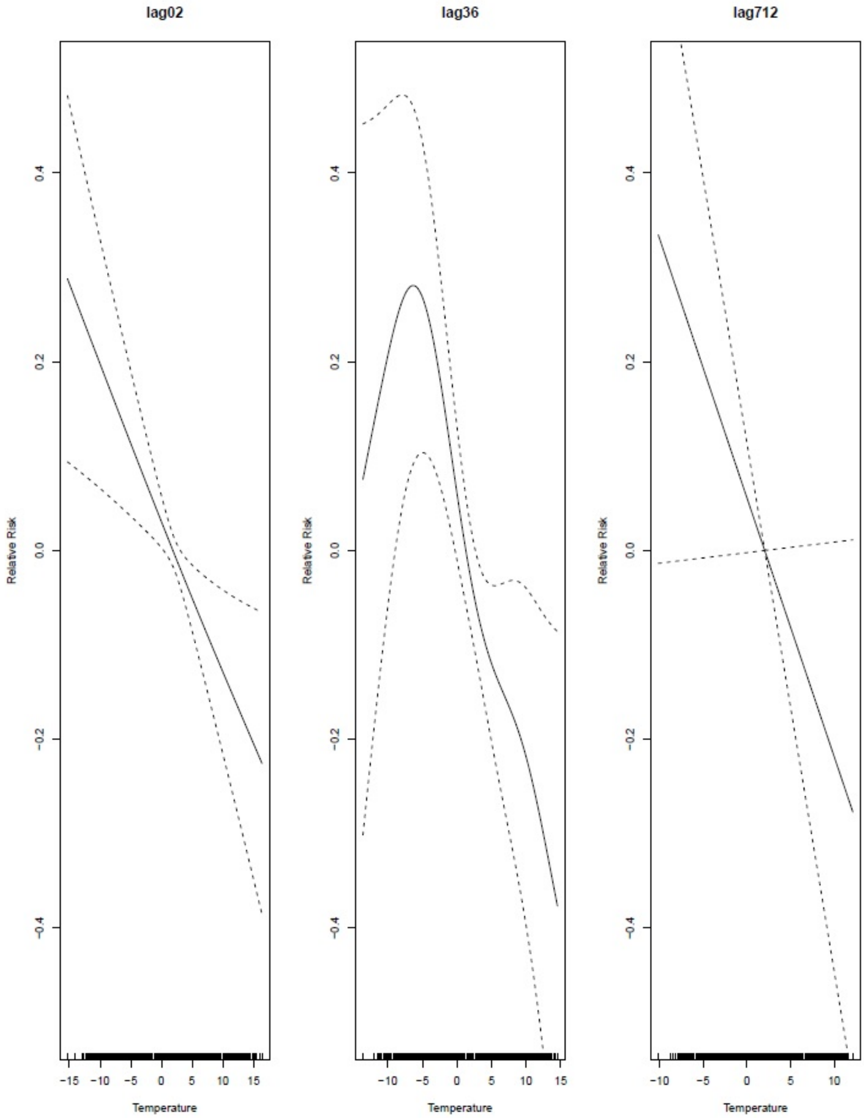


Figure 3: Relationship between temperature and mortality (log relative risk) for different lags during the period 1860−1909

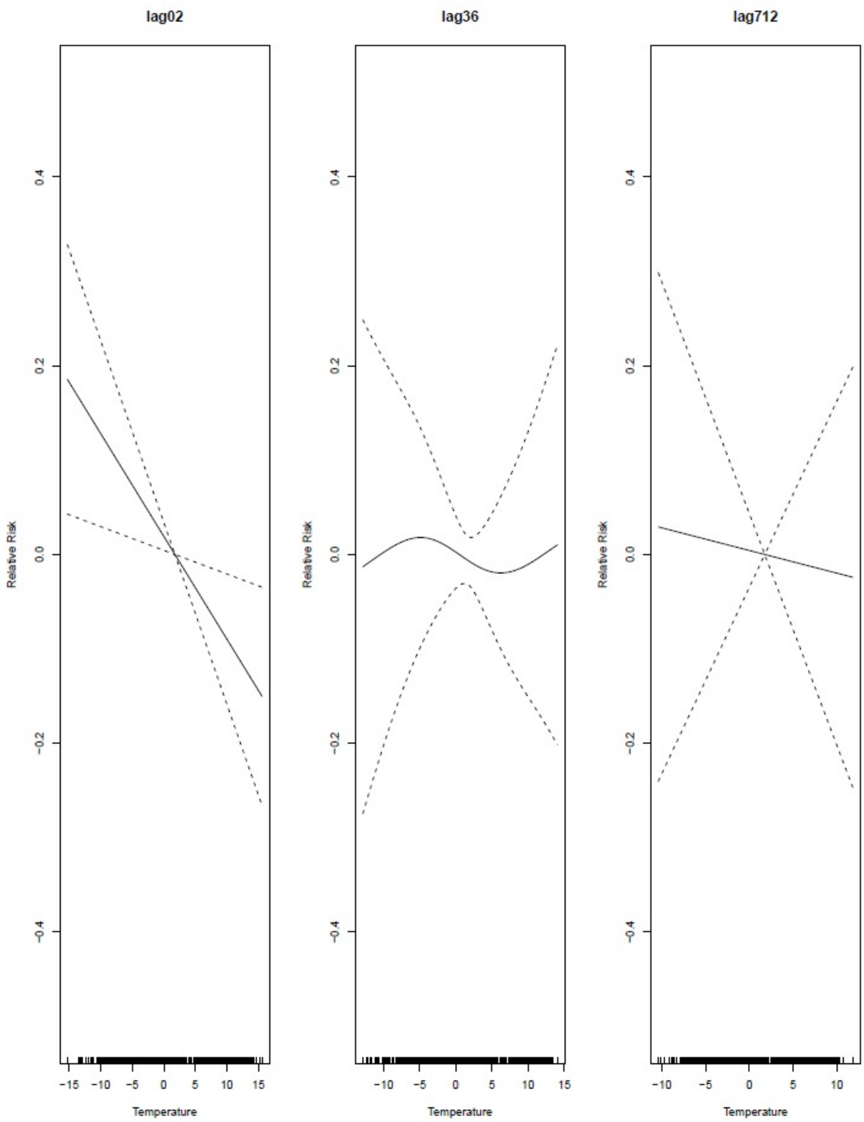


Figure 4: Relationship between temperature and mortality (log relative risk) for different lags during the period 1910−1950

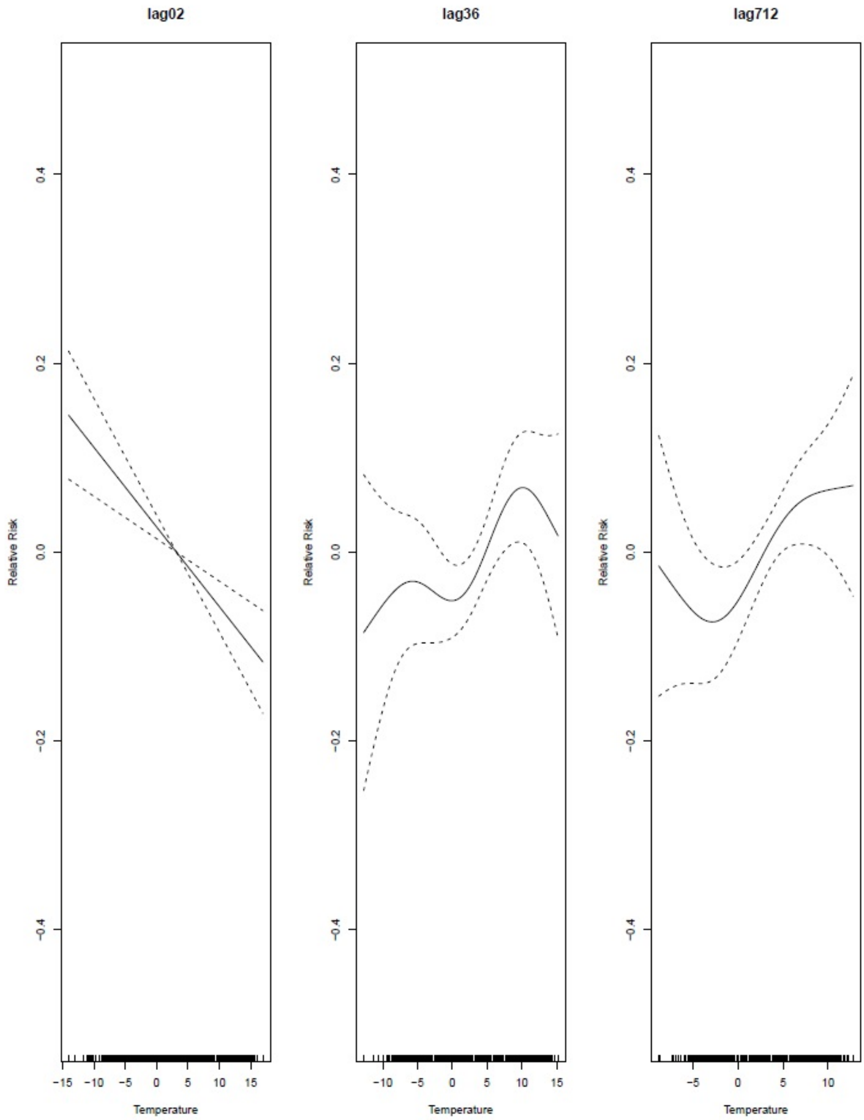


Figure 5: Relationship between precipitation and mortality (log relative risk) for different lags during the period 1800−1859

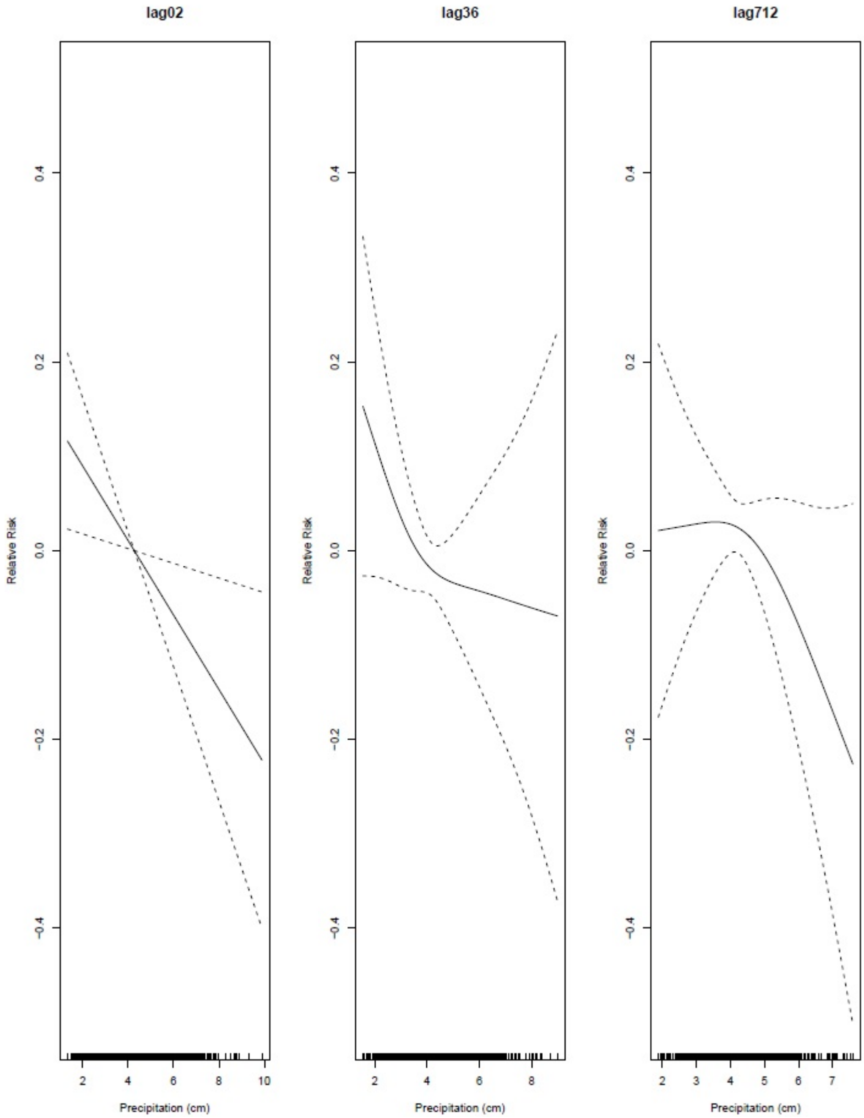


Figure 6: Relationship between precipitation and mortality (log relative risk) for different lags during the period 1860−1909

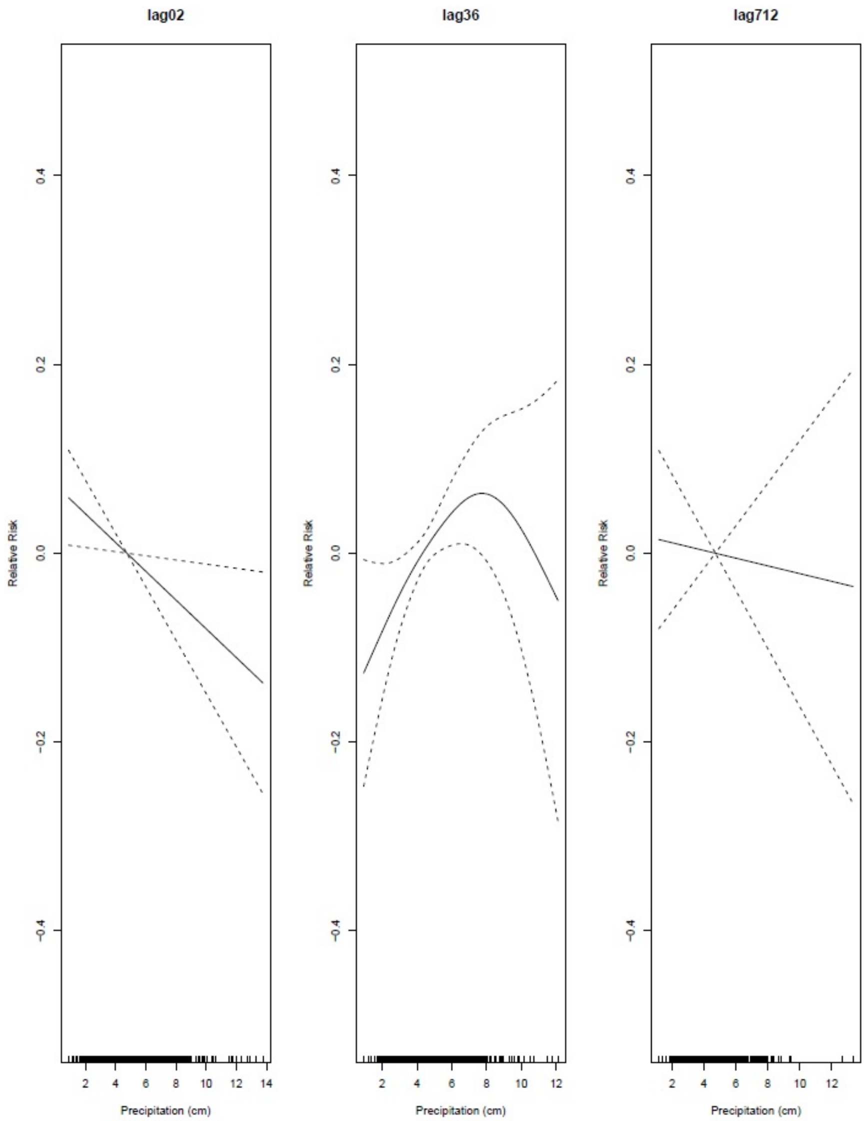
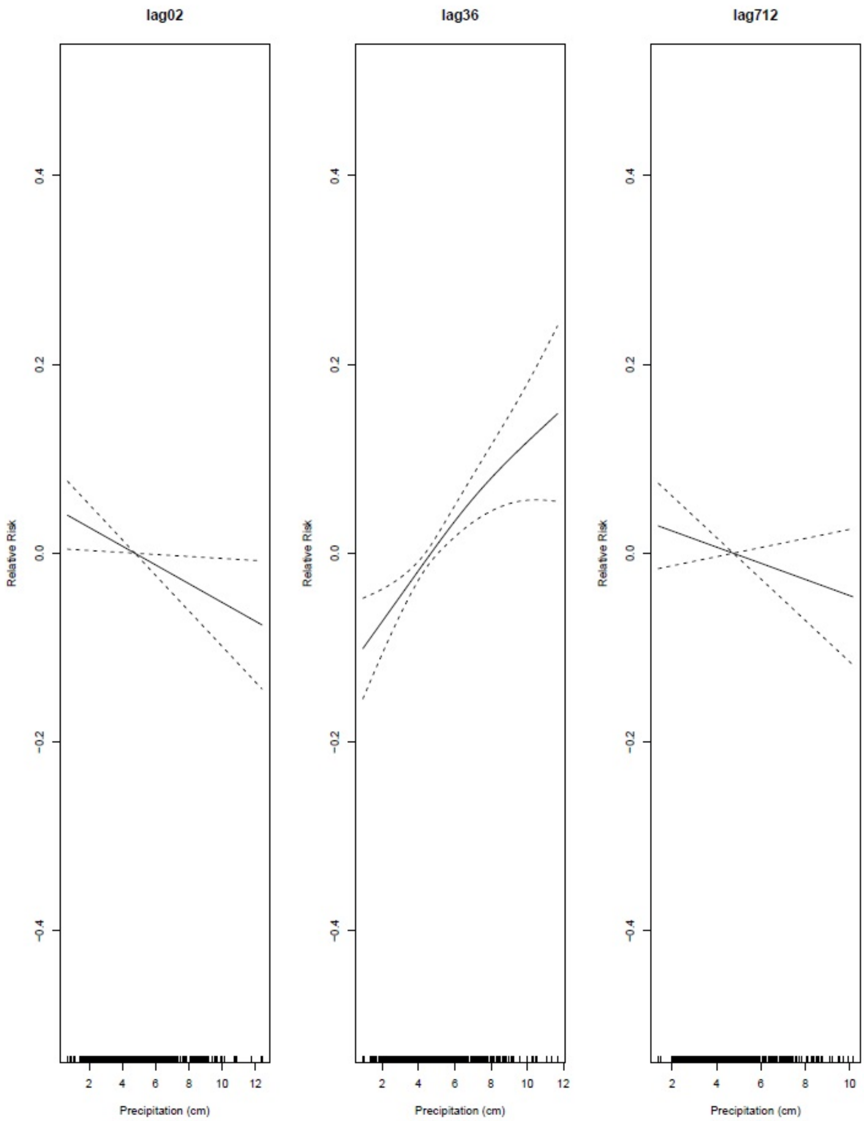


Figure 7: Relationship between precipitation and mortality (log relative risk) for different lags during the period 1910−1950



Supplementary table

Table 1: Relative risks and 95% confidence intervals of mortality associated with a unit increase in monthly mean temperature and monthly cumulative precipitation when including harvest failure in the model

Temperature 1800−1859		Temperature 1860−1909		Precipitation 1800−1859		Precipitation 1860−1909	
Lag	Total Mortality (ns)	Lag	Total Mortality (ns)	Lag	Total Mortality (ns)	Lag	Total Mortality (ns)
02	0.986 (0.976–0.997)	02	0.989 (0.981–0.997)	02	0.960 (0.930–0.991)	02	0.984 (0.971–0.996)
36	0.977 (0.956–0.997)	36	0.999 (0.983–1.012)	36	0.975 (0.921–1.033)	36	1.018 (0.998–1.0387)
712	0.980 (0.953–1.007)	712	0.998 (9.977–1.012)	712	0.968 (0.900–1.042)	712	0.991 (0.966–1.017)

Notes: ns indicates that harvest failure the previous year was not statistically significant at the 5% level.

Supplementary material 1

Reconstruction of precipitation

We reconstructed the precipitation record for Umeå for the time period 1748–1859 (when data were only available for Uppsala) using bootstrapped linear regression modelling. Estimates for monthly precipitation in Umeå were based on the observed relationships between monthly precipitation in Umeå and monthly precipitation in Uppsala for the period 1860–1950. A separate ensemble of regression models was constructed for each month of the year (i.e., there were 12 ensembles of models) because we anticipated that the extent to which precipitation was regionally homogeneous would vary from one season to another associated with large-scale atmospheric circulation patterns. For each month, we generated 100 linear regression models randomly sampling paired observations with replacement from Uppsala as the independent variable and Umeå as the dependent variable from the 1860–1950 time period. We extracted the intercept and slope from each model to build an ensemble of parameter estimates. Subsequently, we used the set of 100 parameter estimates to generate 100 historical monthly precipitation time series for Umeå based on the observations available from Uppsala. Thus, we had 100 available precipitation time series for January 1748–1859 based on one ensemble of 100 parameter estimates, 100 different precipitation time series for February 1748–1859 based on a different ensemble of 100 parameter estimates, and followed the same pattern throughout the calendar year. In a few individual models where the predicted monthly precipitation total was less than zero mm, we set the predicted amount to be exactly zero mm. We merged the 100 time series generated for each month into reconstructions for the period 1749–1859 and extracted the time series with the median total precipitation for the entire period for use in subsequent mortality modelling. Time series from other parts of the distribution of predictions (e.g., the 2.5th percentile and 97.5th percentile) were used for sensitivity analysis.

To test the predictive capacity of this approach, we also generated reconstructions of the Umeå precipitation time series for 1860–1950. Ideally, a portion of this record would have been withheld for model testing prior to reconstruction for the historical period. However, we wanted to maximize the number of available data points for use in the reconstructions and recognized that even the full record (91 years) probably insufficiently captures the full scope of the stochastic nature of precipitation variability between years and locations. The random resampling bootstrap approach is a compromising alternative; each model for Umeå precipitation uses some, but not all of the data points from Umeå that are also being used for evaluating those same models. Our assessment of the models' predictive capacity is thus almost certainly an overestimate but nonetheless provides one useful metric to consider in assessing the total scope of uncertainty in the subsequent associations of mortality and climatic factors.

The total observed monthly precipitation in Umeå for 1860–1950 was 51,811 mm (average: 569 mm/year). The median reconstruction for the same period was a slightly overestimate with a total of 51,847 mm The model reconstructions ranged from a total of 49,530 mm (4.4% low) to 54,050 mm (4.3% high) and the interquartile range for reconstruction totals was 51,190–52,360 mm. A scatterplot comparing the reconstructed values from the median model to the observations for the period 1860–1950 is shown as Figure X. The overall correlation coefficient between the median model and the observations was 0.60; coefficients on a monthly basis were higher for the cool season than the warm season with a highest correlation of 0.63 for November data and a low of 0.27 for June data. Across the ensemble of 100 reconstructions, the correlation coefficients for 1860–1950 ranged from 0.59 to 0.62.

Supplementary Material 2

R-code

#Subset dataset for different periods of time

```
ddb1 <– subset(ddb, year %in% ((1800:1859)))
ddb2 <– subset(ddb, year %in% ((1860:1909)))
ddb3 <– subset(ddb, year %in% ((1910:1950)))
#Perform analyses (temperature and precipitation)
```

$totMA_{ij}$ <– gam($deaths_i$ ~ umea_var_j02 + umea_ var_j 36 + umea_ var_j 712 + war + flu
+ s(trend,k=60) ,data=ddb_i,family=quasipoisson)

where:

$deaths_i$ is the monthly number of deaths occurring in the study region per study period
i=1–3, 1=1800–1859, 2=1860–1909, 3=1910–1950
umea_varij02 is the three month moving average for lags 0–2 of the monthly temperature or precipitation for each study period
umea_varij36 is the four month moving average for lags 3–6 of the monthly temperature or precipitation for each study period
umea_varij712 is the six month moving average for lags 7–12 of the monthly temperature or precipitation for each study period
i=1–3, 1=1800–1859, 2=1860–1909, 3=1910–1950
j=1–2, 1=temperature, 2=precipitation
war is a binary variable indicating the war between Sweden and Russia (high mortality in September 1809)
flu is a binary variable indicating the Spanish Flu (high mortality due to infectious disease October 1918 to January 1919)
trend variable used in the smooth function for trend (12 observations per year)

Derive the Relative Risks and the 95% Confidence Interval

RRvar_j02 <–c(exp(coefficients($totMA_{ij}$)[2]),
exp(coefficients($totMA_{ij}$)[2]–qnorm(0.975)*sqrt(diag(vcov($totMA_{ij}$)))[2]),
exp(coefficients($totMA_{ij}$)[2]+qnorm(0.975)*sqrt(diag(vcov($totMA_{ij}$)))[2]))

where var_j represents temperature or precipitation
j=1–2, 1=temperature, 2=precipitation
the Relative Risks for lags 3−6 and 7−12 were derived in similarly, changing the position of the coefficients in the $totMA_{ij}$ matrix (3 for lags 3–6 and 4 for lags 7−12).